RELATIONSHIP BETWEEN ROAD CONSTRUCTION METHODS AND POST-CONSTRUCTION RATE OF SETTLEMENT: CASE STUDY ON KOTA SAMARAHAN AND SIBU ROADS

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ABSTRACT

In Sarawak, road construction over peat area presents various technical challenges especially for road engineers. As roads built on peat will be subjected to excessive settlement due to traffic loading over time, several methods of construction must be used to mitigate this problem. Past studies indicate that deformation characteristics physical properties of peat soil are important for structural performance especially when constructing roads. This work presents the findings on the relationship between partial replacement method, bamboo mattress with geotextile and replacement method with the post-construction rate of settlement on roads. The methods used to determine the rate of settlement were leveling, settlement gauge and As-built drawing. For this study, several roads in Kota Samarahan and Sibu area were selected. The findings suggest that partial replacement method was found to be suitable for road construction over peat with higher traffic volume. As for replacement method, it is equally suitable with partial replacement method. Conversely, bamboo mattress with geotextile method was preferably suitable for low volume traffic road.

1. INTRODUCTION

Peat is an imperative constituent of the world's wetlands – the dynamic link between land and water, a transition zone where the flow of water, the cycling of nutrients and the energy of the sun combine to produce a unique ecosystem of hydrology, soils and vegetation. In Sarawak about 1.66 million hectares [1] of peat swamp accounts for 13% of the State's total land area. The peat swamps in Sarawak is shown in figure 1. Thus, it is important to determine and select the best methods to be used in road construction in order to mitigate and minimize this problem.

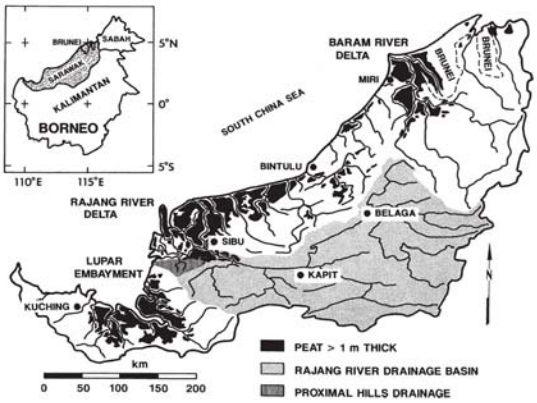

Figure 1: Peat swamps in Sarawak with major peat-forming regions and all peat deposits greater than 1 m thick [2].

The aim of this study is to conduct an analysis on the problems of constructing road on peat area and to recommend the most suitable method(s) to construct it with respect to different depths of peat relative to the density of traffic flows. The main objectives of conducting this study are as to ascertain the common problems associated with construction of roads on peat areas, to scrutinize the various methods used in the construction of roads on different depths of peat, to compare the various methods used for road construction on peat and to evaluate appropriate methods of constructions to be recommended for road construction on peat. However due to lack of proper equipments on method for measuring settlement, this study is limited to measuring the settlement with leveling equipment, settlement gauge and As-Built drawing as recommended by the engineers.

2. LITERATURE REVIEW

Peat and organic soil represent the extreme form of soft soil. They are subjected to instability such as localized sinking and slip failure and also massive primary and long-term settlement when subjected to even moderate load increase [3]. The performance of roads subjected to traffic loading and other environmental conditions was looked into and thus contributed to earlier than expected road settlements. The state of knowledge of peat failures is reported in the reviews of their hydrological controls [4]. Besides, traffic loading performance on the road also contributed to road settlements. Study has been carried out to measure vertical soil stresses beneath the dual wheels and single wheels acting on the road [5].

When constructing a road, subsidence and drainage potential are the most important factors that will influence the potentials of peat soils for sustainable reclamation [6]. Drainage will worsen the problem of excessive settlement due to compaction resulting from the expulsion of free pore water by loading. The subsidence compression again brings the surface to level with the water table. The drains have to be deepened again and the cycle is repeated. The water table ultimately becomes too low to allow for gravitational drainage [7]. Therefore, when a road is constructed above the peat area, it will affect the condition of the road after a period of time if no maintenance is carried out.

To date, there are some methods of construction on road over the peat area namely, settlement of fill over peat, excavation and replacement, pile embankment, geotextile-bamboo fascine mattress and chemical admixtures. The most common method used is the settlement of fill over peat, this is due to its lower cost but it is also very time consuming. Excavation and replacement method is used when dealing with shallow peat. The only successful innovation in handling construction of road on peat is via geotextile-bamboo fascine mattress whereby geotextile acts as separator and bamboo fascine mattress acts as reinforcement [8]. Furthermore, chemical admixture with addition of the cement admixture could improve the engineering properties of tropical peat soils [9]. Lastly, usage of lightweight tyre bales as a foundation material is a successful applications in USA (New York State) and UK whereby geotextile is used as separator between the in-situ soil and the tyre bales [10].

3. METHODOLOGY

In this research, data from relevant agencies and private consultant was collected. Interview with the government and private agencies was conducted in order to obtain specific data on method of construction on peat and others. Books, specification and other related documents or journals were used to acquire more information on the types of road construction over peat namely settlement of fill over peat, excavation and replacement, and geotextile-bamboo fascine mattress. Moreover, settlement of road determined through leveling (Kuching-Samarahan-Asajaya Expressway), settlement gauge (Nang Sang-Teku link road, Sibu) and AS-built drawing (Sungai Bidut road, Sibu) with respect to traffic study were carried out to define the Level of Service (LOS) of the particular road. Therefore, the respective road was determined in terms of LOS and compared with the settlement of road, characteristics and depths of peat in order to identify the problems that occur. Subsequently, the mechanisms of each method were investigated as the primary objective of this study.

4. DATA ANALYSIS AND DISCUSSION

All the information and data collected from the interviewees were based on engineers' experiences when dealing with construction of roads on peat. The engineer's views and opinions were analyzed so that proper recommendation to improve construction of roads on peat can be made. This was done to come out with appropriate methods to construct roads on peat.

i. Kuching-Samarahan-Asajaya Expressway

The Kuching-Samarahan-Asajaya Expressway area mainly consist of recent deltaic and estuarine alluvia deposits that are predominantly silt and clay with lesser amounts of sand and gravel with some varying amounts of organic contents and woody remains in the silt and clay. The total thickness of silt and clay can vary from 6m to 30m. Additionally, the project of Kuching-Samarahan-Asajaya Expressway involves 11km of road from Kuching Outer Link Road to Batang Samarahan river. The construction period of this road was in May 2005 until November 2007. This road is classified as urban road constructed under state project. From the soil investigation report, peat occurs over soft clay in the area between CH3+700 and CH6+400. The peat depth is recorded between 1 to 4.5m deep and is dome shaped which occupies approximately 24,500 m^2 of the area. The treatment used to treat the road construction over peat was bamboo-mattress with geotextile. The Kuching-Samarahan-Asajaya Expressway is classified as level terrain segments where heavy vehicles are able to maintain the same speed as passenger cars throughout the segment. The data taken are listed in the Table 1.

Table 1: Geometric data for Kuching-Samarahan-Asajaya Expressway

Geometric Data	
Number of lanes	4
Lane width	3.5 m
Lateral clearance	1.8 m
Median	4m
Access-point density	0.67
Specific grade or general terrain	Level
Base FFS	100km/h
Demand	
Length of analysis period	15 min
PHF	0.82
Heavy vehicle	0.0048
Driver population factor	1.00

The flow rate and free flow speed for Kuching-Samarahan-Asajaya Expressway is 1256pc/hr/ln and 98.33 km/hr respectively. Therefore, the current Level of Service (LOS) for Kuching-Samarahan-Asajaya Expressway is classified as C.

The analysis on the settlement for the Kuching-Samarahan-Asajaya Expressway was taken by levelling at CH 3+700 using bench marks of 5.170m from in front of UNIMAS' former Faculty of Engineering, East Campus. The results are calculated using rise and fall method. Details on the road are recorded in Table 2 and the settlement of the road is determined at CH 3+700 from the actual construction drawing.

Table 2: Details on Kuching-Samarahan-Asajaya Expressway's level.

Details	**Height (mm)**
Finished road level	7100
Current road level taken from leveling	6848
Settlement of road at CH 3+700	252

ii. Nang Sang – Teku Road, Sibu

Sibu is a town and the capital of Sibu District in Sibu division, Sarawak east Malaysia. It is located at the confluence of the Rajang and Igan River, some 60km from the ocean. Peat covers an area of 540,800km^2 in Sibu town. The Nang Sang-Teku road which is about 10km from Sibu town was constructed in September 2005 under the supervision of Jabatan Kerja Jaya (JKR), Sibu and completed in April 2008. The road was opened to the public for six months during which the traffic study and settlement measurement on the road were carried out. The road was classified as a rural road under state project. The maximum peat depth of 10m was measured on the site and 80% of the area was covered with peat. The conventional method of partial replacement was used in constructing the Nang Sang-Teku road. Nang Sang – Teku road is classified as level terrain segments where heavy vehicles are able to maintain the same speed as passenger cars throughout the segment.

Accordingly, the Level Of Service criteria for two-lane highway (Highway Capacity Manual 2000) classified Nang Sang-Teku road, Sibu as LOS F. The analysis on the settlement for the Nang Sang-Teku road was taken from the settlement gauge at CH 0+125. Thus, details on the road are recorded in Table 3.

Table 3: Details on Nang Sang – Teku road's level.

Details	Height (mm)
Settlement gauge from the ground level to the tip of the hole	940
Height of the steel pipe from the existing road level	250
Existing ground level	3450
Proposed road crown level	4170
Current road level	4140
Settlement of road from proposed crown level	30

iii. Sungai Bidut Road, Sibu

Sungai Bidut road that connected to proposed university is located 25km from Sibu Town is covered with peat. This project was supervised by Jurutera Jasa (Sarawak) Sdn. Bhd., Kuching and was completed in December 2007 with a total distance of 13.3km. The road was opened to the public for nine months. The road was classified as a rural road under state project. Based on the borehole information, the top 6m deep was very soft peat soils and fill over with sand due to its low bearing capacity and the subsequent very soft clay (24m deep) were treated with Prefabricated Vertical Drain (PVD) to accelerate the rate of consolidation. In Sungai Bidut road, Sibu, replacement method was used.

Sungai Bidut road is classified as level terrain segments where heavy vehicles are able to maintain the same speed as passenger cars throughout the segment. Accordingly, the Level Of Service criteria for two-lane highway (HCM 2000) classified Sungai Bidut, Sibu as LOS A.

The analysis on the settlement for the Sungai Bidut road was taken by comparison between the road crown levels with As-built drawing based on nine months of operation. From the finding, it is found that the differences in levels are 10mm which is the average settlement.

From the analysis and the results obtained, the most appropriate method of construction used to construct a road on peat is generated. The choice of construction method in the areas underlay the peat depth, level of service (LOS) and the settlement of the road after construction. These studies also define the pavement layers laid on the road. The following data listed in Table 4 summarizes the three methods of construction applied to these three projects.

Table 4: Summary of method of construction applied and the parameter used.

Location of Road	Method of Construction	Level of Service (LOS)	Depth of Peat (m)	Peat Properties	Operation Time (months)	Road Pavement Thickness (mm)	Finished Road Level (mm)	Current Road Level (mm)	Average Settlement of Road (mm)
Kuching-Samarahan-Asajaya Expressway	Bamboo-mattress with geotextile	C	4.5	Bulk density =0.1g/m^3 Shear strength=<10kPa Compressibility index=0.22	12	Wearing Course=50 Binder Course=50 Road Base=250 Sub Base=300	7100	6848	252
Nang Sang-Teku road, Sibu	Partial replacement method	F	10	Bulk density =0.08g/m^3 Shear strength=4.87kPa Compressibility index=1.045	6	Wearing Course=40 Binder Course=60 Road Base=225 Sub Base=275	4170	4140	30
Sungai Bidut road, Sibu	Replacement method	A	6	Bulk density =0.12g/m^3 Shear strength=6.8kPa Compressibility index=1.12	9	Wearing Course=40 Binder Course=60 Road Base=250 Sub Base=200	3500-7000	3180-7000	10

5. CONCLUSION

This work presents the findings on the relationship between partial replacement method, bamboo mattress with geotextile and replacement method with the post-construction rate of settlement on roads. The methods used to determine the rate of settlement were leveling, settlement gauge and As-built drawing. For this study, an expressway in Kota Samarahan and two sections of Sibu roads were selected as comparison. The findings suggest that partial replacement method was found to be suitable for road construction over deeper peat with higher traffic volume. As for replacement method, it is suitable for lower traffic volume as indicated in the Table 6. Conversely, bamboo mattress with geotextile method was preferably suitable for shallow peat depth with lower traffic volume. On the other hand, the findings also suggested that the settlement of road varies with depth of peat, operation time, level of service, peat properties and pavement thickness.

6. RECOMMENDATIONS

By increasing knowledge of problems presented by peat and the methods that can be used to solve those problems, it is hope that problems on peat soils can be tackled in the future. To obtain a precise method for construction over peat soils, it is recommended that more site investigation reports on peat be used together with the method of construction of the road. Furthermore, the precise method of construction should also consider the physical parameters of peat. Moreover, the level of the road should be carried out every year to verify the settlement of the road with the estimated settlement. The important things that should be highlighted for road construction works are time of construction period, site condition, material's condition especially bitumen, numbers of passes by the compactor, work constraint and equipment mobility.

7. ACKNOWLEDGEMENT

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